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## A comparative analysis of three manufacturers of science probeware for the classroom

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A COMPARATIVE ANALYSIS OF THREE MANUFACTURERS  
OF SCIENCE PROBEWARE FOR THE CLASSROOM

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A Project  
Presented to the  
Faculty of  
California State University,  
San Bernardino

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In Partial Fulfillment  
of the Requirements for the Degree  
Master of Arts  
in  
Education:  
Science Education

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by  
Matthew Phillip Reisenhofer

June 2006

A COMPARATIVE ANALYSIS OF THREE MANUFACTURERS  
OF SCIENCE PROBEWARE FOR THE CLASSROOM

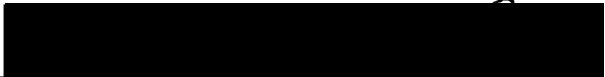
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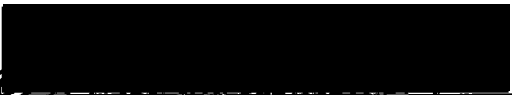
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by  
Matthew Phillip Reisenhofer  
June 2006

Approved by:

  
Dr. Herbert Brunkhorst, First Reader

6-8-06  
Date

  
Dr. Bonnie J. Brunkhorst, Second Reader

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## ABSTRACT

The United States has driven the world economy due to its supremacy in science and technology, but our past supremacy has recently been challenged. Science education needs to play an important role in regaining our lead in science and technology worldwide. The need to accelerate our science education programs is more evident than ever but with a teaching workforce lacking the appropriate education or experience, we need to enhance teaching methods and provide the appropriate resources for teachers to make a successful and productive classroom. Probeware can play a pivotal role in the transformation of the science classroom into a place of scientific investigation. This project is designed to begin the process of familiarizing teachers with probeware and its effectiveness in inquiry teaching and learning and assists teachers in selecting and evaluating appropriate probeware materials from a variety of vendors. Based on the data in this study no manufacturer proved themselves to be clearly the best. The decision on which to buy a particular manufacturers probeware turned out to be far more complex. The option of which interface to purchase easily becomes a choice of which characteristics are more important and useful in a teacher's classroom.

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## CHAPTER ONE

### BACKGROUND

#### Introduction

The United States has driven the world economy due to its supremacy in science and technology. "The dominant position of the United States depended substantially on our own strong commitment to science and technology and on the comparative weakness of much of the rest of the world" (Committee on Science, Engineering, and Public Policy, 2006, p. 9-2). Our past supremacy has recently been challenged. Although we have maintained a level of devotion to science and technology that was previously acceptable, competing countries have increased their support and commitment to science and technology. "The age of relatively unchallenged US leadership is ending" (Committee on Science, Engineering, and Public Policy, 2006, p. 9-2). The need to accelerate our science education programs is more evident than ever. Science and technology hold an important role in the future of our nation as well as the future of our students but students are unable to distinguish between the two (National Research Council, 1996, p. 191). "This lack of distinction between science and technology is further confused by

students' positive perceptions of science, as when they associated it with medical research and use the common phrase "scientific progress." However, their association of technology is often with environmental problems and another common phrase, "technological problems" (National Research Council, 1996, p. 191). Using technology as well as allowing the students to explore and use technology as they problem solve in science, will hopefully contribute to the change in their perception of science and technology. "The relationship between science and technology is so close that any presentation of science without developing and understanding of technology would portray an inaccurate picture of science" (National Research Council, 1996, p. 190).

Science education needs to play an important role in regaining our lead in science and technology worldwide. Other countries are making advances by leaps and bounds while we are just maintaining the status quo. "The US system of public education must lay the foundation for developing a workforce that is literate in mathematics and science, among other subjects" (Committee on Science, Engineering, and Public Policy, 2006, p. 5-1). With the use of inquiry-based teaching and learning in science, understanding science and the way it works should

definitely increase. "Students who use inquiry to learn science engage in many of the same activities and thinking processes used by scientists who are seeking to expand human knowledge of the natural world" (National Research Council, 2000, p. 1). The public school system can play an important role in preparing our students for the future, the future that can and will include more science and technology.

Teachers play one of the most important roles in fostering a revived interest in science and technology. "Excellent teachers inspire young people to develop analytical and problem-solving skills, the ability to interpret information and communicate what they learn, and ultimately to master conceptual understanding" (Committee on Science, Engineering, and Public Policy, 2006, p. 5-1). Teachers also can contribute to the diminished interest in science and technology. With a science teaching community with minimal experience in the subject they teach, we can only be setting up students for failure. "A US high school student has a 70% likelihood of being taught English by a teacher with a degree in English but about a 40% chance of studying chemistry with a teacher who was a chemistry major" (Committee on Science, Engineering, and Public Policy, 2006, p. 5-2). With a teaching workforce lacking

the appropriate education or experience, we need to enhance teaching methods and provide the appropriate resources for teachers to make a successful and productive classroom. The science education and science community place great emphasis on inquiry based lesson design. It is a preferred and recommended method for the retention of the material, "inquiry has been identified as the preferred method of instruction within the teaching and professional development sections from the NSES" (Llewellyn, 2005, p. ix).

In the age of technology we live in, we have many tools at our fingertips that can enhance the inquiry teaching and learning, including the relationships between science and technology. One such tool is probeware, also known as data loggers, which are instruments used to record real time data, such as temperature, light intensity, pH, voltage, and force. Probes are the sensors that attach to the probeware, or data logger that measures the desired data and sends it to the computer for analysis. In this project, the author will use the term probeware exclusively, but other research and manufacturers use both terms interchangeably. Used with an inquiry designed lesson, probes allow the students to explore the topic at hand in real time and draw

conclusions from their own real scientific investigations. Probes also give teachers a chance to demonstrate difficult scientific concepts in the classroom.

Probeware can play a pivotal role in the transformation of the science classroom into a place of scientific investigation. Unfortunately, with the current science education workforce, there needs to be extra steps taken to begin the process of revitalizing the interest in science and technology. We can no longer wish for a change in the quality of our science teacher workforce; there is no better time than now to start the process of improving the quality of science instruction. The introduction of new technology aimed at helping teachers improve the quality of science instruction in the classroom has to be a deliberate process. Due to the lack of experience that a majority of teachers have with probe-related technology, the technology easily becomes a time burden in their lives which ultimately meets its final fate of dust collecting in a school storage room. Without taking the necessary steps to familiarize teachers with the technology that is designed for their use, we are wasting school money with technology purchases. The ultimate goal of this project is to impact teachers' attitudes toward the use of new technology in the classroom. "Teachers intent to use

technologies resources begins with their attitude toward using them in their classroom" (Chao, 2005, p. 841). With an improved attitude toward the use of technology comes an improved opportunity of its use to teach inquiry-based science in the classroom. In the author's experience, teachers are eager to buy the new probeware technology, but when it arrives, they do not know how to use it or implement it in developing an inquiry and standards-based lesson.

#### Purpose of the Project

This project represents a professional development pathway to begin familiarizing teachers with probeware and its effectiveness in inquiry teaching and learning and assists teachers in selecting and evaluating appropriate probeware materials from a variety of vendors. This project will evaluate and assess the probes and associated probeware of three manufacturers using a variety of criteria that are essential information for a consumer. This project will examine and evaluate the probes and related probeware of three manufacturers and identify the benefits and liabilities each of them hold. The first set of probes that will be examined in full is by the company Pasco Scientific, or Pasco for short. Pasco has two lines

of Probeware, ScienceWorkshop and Pasport. For this project, ScienceWorkshop was the product chosen for the comparison.

The second company will be Vernier, which has a probeware product by the name of LabPro. Vernier was chosen due to their large product line and experience in the probeware market. The third manufacturer in the comparison is from a company by the name of Onset, which has a product line by the name of HOB0. Onset was chosen due to their ongoing commitment to aiding teachers with the use of probeware in the classroom.

The second criterion used in the selection of the probeware was availability. Each is readily available without any additional purchases. Also, the review of the three manufacturer's will give a teacher, prospective consumer, a wide enough range to make an informed decision of their particular purchase.

In addition to the introduction of probeware, three exemplary experiments using probeware will also be introduced. The experiments will be specifically chosen to test each of the criteria for comparison. There will be three chosen, one from each manufacturer, to ensure the equity that each will be run under the conditions designed for their product. The three experiments will be conducted



with each manufacturer's probeware to identify any pros and cons the teacher might encounter while using probeware. With just an introduction to probeware, the teachers do not get a chance to see how the probe can be implemented in the classroom. With the introduction of the exemplary experiments, the teacher will have the opportunity to see how to implement the technology. This project will compare and contrast the three different manufacturers under typical usage.

#### Context of the Problem

The delivery of science content is another highly debated issue within the educational world. On one side of the debate is the support for traditional direct instruction in the classroom. On the other side of the debate is the support for inquiry teaching and learning in the classroom. When viewed from one extreme to the other, neither method seems to be the one and only method to effectively teach students. "Experience and understanding must go together" (National Research Council, 2000, p. 14). It is a blend of the two methods that is desired by the science education community. "Doing science requires more than memorizing lots of content facts; it also requires knowledge about the processes involved in

scientific investigation and knowledge of the processes of science" (Bybee, 2002, p. 20). Students need the experiences in order to understand the facts. "They should learn the language of science and be able to explain their experiments in the vocabularies of science" (Bybee, 2002, p. 20). Probeware can actually enhance student-centered activities as well as teacher-centered demonstrations or lectures.

Technology holds beneficial aspects to our everyday teaching but it also has many challenges for us as well. Technology provides us with instructional tools that can develop concepts that we normally would not be able to develop in the classroom. Simulation software can illustrate the atomic structure and electron clouds in ways that plastic models or textbook descriptions could never reach. The problem with the use of technology is that there needs to be a technician that understands how to use it. Without general operational knowledge, technology becomes useless. There is a definite need to help teachers understand the new technology. Based on this author's personal experience schools spend large amounts of money on the latest and greatest technology, but then the technology goes to waste and is not used due to the

fact that no one in the school knows how to use it. School districts are wasting time, money, and technology.

#### Limitations and Delimitations

There are many manufacturers of probeware that are not included in this project. Furthermore, the three manufacturers chosen for the project each have more than one product line of probeware. The three manufacturers and their particular product lines were chosen by convenience of availability. Convenience was also the motive on the selection of the type of computer to run the probeware on. For this project, a PC type computer was used, although each product line is compatible with Macintosh computers as well. The steps in revitalizing the interest in science and technology are small and slow. Most probeware is very similar in design and with the knowledge of the three different types covered in this project, a science teacher should have little trouble in the operation of other products or with the same products on a Macintosh computer.

The basic operation of computers was purposefully left out of the project's scope. Understandably, computers provide one of the greatest problems anyone has with technology. Due to the range of problems teachers have

with computers, it would be impossible to address each and every scenario someone could encounter with a computer. The discussion on computers will be limited to their direct relationship with probeware, the installation and operation of the probeware software and hardware.

## CHAPTER TWO

### REVIEW OF THE LITERATURE

#### Introduction

To completely address the entire subject of probeware in the classroom, one must examine the research of how people learn, scientific inquiry in the classroom as well as the technological uses of probeware in the classroom and the relationship between science and technology.

#### How People Learn

Before we can address the research, we need to acquire an understanding of how people learn. Identifying the attributes that lead to an ideal learning situation can help identify if probeware can fit the mold. Theories in education just like in science are an evolving process. "Contemporary learning theories are active and are frequently termed cognitive (in opposition to behavioral). They assume that learning requires activity on the part of the learner - that something is happening in the mind and that it is possible to infer what that is from the actions of the person engaged in learning" (Bybee, 2002, p. 8). The key to the learning theory is the student taking an active role in the learning process. Science education places a large emphasis on meaningful student activity

that relates both the science content as well as the activity. "John Dewey (1900), who held that for learning to take place students had to actively engage in meaningful problem solving, was the first to propose an active learning theory" (Bybee, 2002, p. 8). Dewey viewed learning like pieces of a puzzle that were fit together in a moment of insight (Bybee, 2002, p. 8). It is the creation of these moments of insight that can help students successfully construct a better understanding of the content.

When discussing learning theory, constructivism is a term that definitely has to be considered because it is based on research reported on leading scientific organizations. There are multiple meanings of constructivism but ambiguous features lie within. "Despite the multiplicity of connotations, there are some recognized features of constructivism: learning is active; learning is the interaction of ideas and processes; new knowledge is built on prior knowledge; learning is enhanced when situated in contexts that students find familiar and meaningful; complex problems that have multiple solutions enhance learning; and learning is augmented when students engage in discussions of the ideas and processes involved" (Bybee, 2002, p. 9). Throughout

the research on how people learn the main idea that students need to learn more than just the facts is a concept that keeps resurfacing. Designing a curriculum based around this particular idea should become a priority. Integrating the fact learning with the integration of the facts in contextual processes will help solidify the ideas. Inquiry is the science answer to improving on the quality of the instruction given to students. Using inquiry in the classroom will meet the requirements for how people learn.

### Inquiry Teaching and Learning

The first area that needs to be addressed is the research on scientific inquiry in science education. Inquiry teaching is at the center of many educational debates, but is a tried and true method for the delivery of science content. "Inquiry is a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather; analyze, and interpret data; proposing answers, explanations, and predictions; and communicating results" (National Research Council, 2000,

p. 13-14). In a position statement the National Science Teachers Association writes, "Scientific inquiry reflects how scientists come to understand the natural world, and it is at the heart of how students learn" (NSTA Board of Directors, 2004). The National Science Teachers Association is among the science population in support of inquiry in the classroom. The position statement continues, "Understanding science content is significantly enhanced when ideas are anchored to inquiry experiences" (NSTA Board of Directors, 2004). At the heart of how people learn science, inquiry provides students a chance to relate a concept with an experience. The National Research Council has released a report entitled "How People Learn" and in this report several key findings lend support towards the use of inquiry in the classroom (National Research Council, 2000, p. 116). Among the findings, the most important include, "Understanding science is more than knowing facts," "Students formulate new knowledge by modifying and refining their current concepts and by adding new concepts to what they already know," "Effective learning requires that students take control of their own learning." "The ability to apply knowledge to novel situations, that is, transfer of learning, is affected by the degree to which students



learn with understanding." "Learning is mediated by the social environment in which learners interact with others" (National Research Council, 2000, p. 116-119). These findings fit flawlessly into the inquiry lesson approach. With the use of inquiry in the classroom, the students will get exposure to the science content with an appropriate sequence of experiences that optimize the learning process. With the necessary scaffolding in place, student will soon be prepared to ask scientific questions and know how and when to gather the necessary evidence and provide explanations for their observations and investigations. These are the processes that industrial scientists use everyday to solve problems. If we can instill this problem solving and inquiring behavior in students today, the future for the student as well as the nation can be much brighter. The need for students entering the workplace with these skills is obvious, "New employees need to be flexible and adaptable, able to solve unforeseen problems and do their best work in teams" (Bertrand, 2005, p. 15). The demand for a highly qualified and prepared workforce is apparent and unfortunately our students are not properly filling the positions, "students in school today may not be adequately prepared for tomorrow's job setting and predict they will face

increasing competition for jobs from countries where citizens have stronger science and math literacy skills" (Bertrand, 2005, p. 15). With an increase in competition of jobs, there needs to be a change in education to regain control of the market and stabilize our students future. Inquiry fits the mold of change, it will follow how we know students learn as well as increase science learning. The question left is where is the debate between direct instruction and inquiry lesson design?

The main debate stems from a misunderstanding of what inquiry teaching is and how to implement the methods in a normal classroom setting. The opposition to inquiry in the classroom has been the inaccurate belief that inquiry is the self discovery of the science content, which could have an opposite effect to what teachers actually intend. The students are expected to discover the content with little or no guidance from the teacher. With this misguided belief, it is easy to see why there is a strong opposition to the method. "However, student attention to selective information/data/experience may simply serve to reinforce existing ideas/concepts. While this may be acceptable if the student's existing idea is in keeping with the scientists' view, it becomes problematical when the students' existing idea is incompatible with the

scientists' view" (Rodrigues, Pearce, & Livett, 2001, p. 41). Using what the student already knows, a student may not focus on the appropriate data and just confirm their inaccurate view of the topic at hand. A teacher's role in an inquiry lesson is just as important as in a direct instruction lesson, perhaps more. The teacher provides the necessary scaffolding necessary for the students to make the appropriate connections between experience and content. "Without appropriate scaffolds...the intended learning experience may be significantly different to the experienced learning" (Rodrigues et al., 2001, p. 42). If there was a better understanding of inquiry, the opposition would be foolish not to embrace it as a delivery method for science content. "The debate about whether to emphasize content or process in school science has subsided in favor of the role of inquiry in supporting the construction of conceptual understanding. National and local jurisdictions have recommended that science education programs be inquiry-based" (Rowell, 2004, p. 915). Safely embracing the natural learning style that young children use to discover the world around them and place the same elements in the classroom, leads to the actual understanding of the science as they perform not memorize science. The teacher's role in the classroom does

change, but plays perhaps a more important role in the guidance of their student's learning.

### Technology in the Classroom

The second area of research is the use of technology in the classroom. Probeware falls under the category of technology. Understanding the research related to technology can be beneficial to this project, because probeware is technology designed for the classroom, and aid in the ultimate goal of familiarizing teachers with this new technology. By nature, with the use of real time data, probeware can advance the science classroom to a place of investigation. The students are forced to work outside of a prescribed box and not know the results of the experiment in advance. Using probeware can get students asking questions and investigating the answers. Cook book labs with predictable results can be replaced to insure student participation and engagement. Classroom instruction can easily make the turn towards inquiry. There are many tools that help increase inquiry learning. Technology provides several beneficial tools.

The use of technology in the classroom has several benefits as well as its own share of implications. New technology is made available yearly to teachers for

enhancing instruction, but largely this new technology remains under utilized. Technology gives teachers a chance to change the classroom to a student-centered environment, making it easier for the students to develop a healthier more self reliant role in their own education (Muir-Herzig, 2004). "Technology can help students including at-risk students learn and practice a variety of skills and improves their attitudes to learning" (Muir-Herzig, 2004, p. 113). Students can develop and improve the critical thinking skills and essential skills of inquiry. The use of technology in a science classroom gives students a chance to experience science the same way professionals do. "Technology provides access to up-to-date digital content, as well as an array of tools for modeling, visualizing, collecting and analyzing data, and enhancing communication" (Appel et al., 2001, p. 70). Using technology in the classroom changes the dynamics of the class. The teacher's role becomes a vital key to the students understanding of the content presented to them through the use of the technology.

In addition to understanding the benefits technology holds in education, understanding the drawbacks is essential. The question that needs to be addressed is: Why aren't teachers utilizing the new technology and choosing

to pass on all the benefits that come with it? Study after study has come out identifying the drawbacks technology holds, but none as applicable as Todd Oppenheimer and his book, *The Flickering Mind: The False Promise of Technology in the Classroom and How Learning Can be Saved*.

Oppenheimer explores what he calls the false promise of technology. He discusses the gap between the promise technology is the fix-all for the educational system and the reality of the wasted time and money spent on technology that is rarely used in the classroom. From the introduction of computer technology, it has been sold as the future in many aspects. Technology has been sold to the educational fields as the way to help the failing education system. Technology and technology alone will improve the quality of instruction and education given to our students. Then, with the purchase and attempted use of technology, there are little to no changes made in the school system. Teachers are left with an unfulfilled feeling that technology has let them down. Oppenheimer discusses a school that followed this unfortunate path, Belridge Elementary School, in McKittrick California. "Belridge invested \$4.3 million in computer technology over a four-year period for a student body of no more than sixty children. The investment filled the school with

futuristic gear of all kinds - laser-disk players, television production studios, shiny new Apple computers, piles of software, even email accounts at a time when most schools hadn't even heard of the internet. Teachers modernized their instruction methods too" (Oppenheimer, 2003, p. 392). Belridge is an example of a school that was relying too much on the false promise of technology. With their new investment in what they thought was a bright future for their students, they were only let down. "Several years after everything appeared to be in place, it all came crashing down. When the annual district test scores were reported, they showed that students' performance had actually declined during the computerization years, falling slightly below the national average" (Oppenheimer, 2003, p. 392). The investment in technology had the opposite affect than the one intended. With the decrease in student performance, the school was left scrambling for a plan to pull the students scores up and return the school to the state it was in prior to the technology investment. The school abandoned its high-end approach in attempt to save the school, "ever since the school abandoned its high-end approach to computing, test scores and other measures of academic performance have risen substantially. The school accomplished this by doing

little more than return to the "basics," a move helped considerably by yet another simple solution: small classes" (Oppenheimer, 2003, p. 393). After the return to the "basics," the scores began to rise again. The message was easily sent that technology does not have a positive affect in the classroom. It is cases like these that easily can lead to a discouraged view about the false promises of technology, but this is not the intended message from the author. Oppenheimer would in no way be considered a technology supporter, but the message sent is moderation. Technology in the classroom has its time and place. " If any generalization can be made, it would be that technology is used too intensely in the younger grades and not intensely enough - in the proper areas - in the upper grades" (Oppenheimer, 2003, p. 393). Each research study that shows the benefits of technology in the classroom, can easily be placed in what Oppenheimer called the "proper areas" (Oppenheimer, 2003, p. 393). Even Oppenheimer admits that there is technology that improves the classroom. "Obviously, many programs - such as computerized vocabulary exercises and foreign language drills; graphing software for geometry; data managers and scientific simulations; and basic word-processing software - are already capable of being useful supplements"



(Oppenheimer, 2003, p. 393). Probeware can be placed into this category of useful supplements. The key word is supplements, probeware, or any other technology based tools, are supplements to the instruction necessary to understand the topics at hand. These are tools for instruction, not replacements for other forms of instruction provided by highly qualified teachers.

With the introduction of new technology, comes the introduction of new responsibility for the teachers. The teachers play an important role of teaching the students how to use and technology. The easiest example of new responsibility comes with the introduction of the internet. The internet is a valuable resource in a classroom environment, but it is the teachers' responsibility to teach students how to appropriately use the internet. There are many harmful WebPages that are not designed for the students benefit. "Preventing children from consciously finding inappropriate materials or, even worse, accidentally stumbling onto such materials is absolutely our adult responsibility" (Soloway et al., 2000, p. 20). With this responsibility technology tries to take a leading role. "One popular technique employed by schools is Web filtering" (Soloway et al., 2000, p. 20). The problem with web filtering is that it can only detect

and prevent the viewing of WebPages that contain specific keywords. These key words might be in the WebPages that do contain information beneficial to their assignment. "For example, children won't be able to see medical sites that contain the word breast" (Soloway et al., 2000, p. 20). Just keeping students away from these inappropriate sites is half the battle. The students need to know how to utilize the internet as a resource and evaluate the information it contains. The information on the internet has no review process; anyone with the necessary skills can make a website about almost anything conceivable. The students need to know that the just because it was on the internet doesn't mean it is necessarily true. The teachers need to educate the students on the evaluation process of information it contains.

The next answer to the question of why has technology failed to fulfill the promise, lies within teacher apathy. One of the points that Oppenheimer makes is that "integrating technology into education has become a destructive cycle" (Straub, 2006, p. 261). The destructive cycle he mentions is evident from a teacher standpoint. Technology is a vastly growing area and the operation of a school is a slow process. It takes a school time to make the decision to purchase new technology, then install the

technology, train the staff on how to use the technology, and then have the teachers implement the new technology while providing maintenance and trouble-shooting. During this cycle at the school level, the technology purchased has become out of date. During this process teachers have their own problems with the technology, covered by Oppenheimer in what he calls, "the struggles of the teacher" (Straub, 2006, p. 259). With the ups and downs that technology provides, even the experienced technician can have trouble, so for the untrained teacher, the downtime technology provides can give reason enough for staying away from it. "However, expert technology integrators understand and come to terms with the sometimes rocky relationship technology offers. It is not a matter of whether the technology will fail, it is when will the technology fail. For some teachers, the idea that it will fail is enough not to implement" (Straub, 2006, p. 259). Teachers' training appears to play a pivotal role in the integration process of technology in the classroom. "Barriers to using technology in education includes lack of teacher time, limited access and high costs of equipment, lack of vision or rationale for technology use, lack of teacher training and support, and current assessment practices that may not reflect what is learned

with technology" (Muir-Herzig, 2004, p. 115). With the experience and comfortable usage of technology in their personal time, improved attitude towards technology in the classroom will follow. Teachers need to receive training and given time to learn how to use and trouble shoot the technology they tend to use in the classroom. The training must also include the proper integration of technology with lesson design. The trouble easily extends to all aspects of technology use, even if a teacher knows how to use the technology, it's when to use the technology that is of equal importance. "The need for teacher training and the lack of expertise are major barriers to using the microcomputer and related equipment. With computer competence, teachers' anxiety decreases and their attitudes toward computers improves with hands-on computer literacy courses" (Muir-Herzig, 2004, p. 115).

The one question left to debate is how to appropriately integrate technology in the classroom. This question is extremely important and brings us back to the use of the internet in the classroom, which can be a great resource. The internet provides the students with a vast array of knowledge at their fingertips. The problem is that not all of the information found on the internet is agenda free and reliable. "Teachers must help students

learn techniques to assess this ever-expanding source of data, so that they can be informed consumers of information on the Web. A comprehensive plan defining appropriate uses of technology should include teacher goals and student goals aligned with the district curriculum" (Appel et al., 2001, p. 77). The internet, like technology in the classroom, needs a competent teacher that can provide the appropriate scaffolding students need to make the experience effective.

Another critical piece to the integration of technology puzzle is the professional development provided to the teachers. Professional development must target three areas, "learning how to use the specific software and devices, learning how to successfully infuse technology into science teaching, and using technology for teacher learning, particularly in the science content area" (Appel et al., 2001, p. 78). With the target of these three areas, a change in practice is also targeted. The teachers are shown the benefits of the technology, not just by word of mouth, but by experience with their own use and practice with the technology. The focus must be placed on "teaching and learning, rather than on the technology itself" (Appel et al., 2001, p. 79).

Another important aspect is that teachers must be given "time for practice both outside of the classroom and with students" (Appel et al., 2001, p. 79). Without appropriate time for the teacher to become familiar and comfortable with the technology, the teachers' attitude for the technology may never change. Without a change in attitude towards technology in the classroom, technology may be doomed to an expensive but short lived use in the classroom.

#### Probeware in the Classroom

The final and perhaps the most important area of research that needs to be discussed is the use of probeware in the classroom. Probeware follows the same guidelines of use in the classroom as the general use of technology in the classroom. The scaffolding a teacher provides is essential for its successful use in the classroom. The design of the probeware itself as well as the design of the lesson also plays an important role in its successful integration, "...key factors that impact students' ability ...to engage in science inquiry...(1) the design of the handheld software, and (2) characteristics of the learning activity, such as the complexity of the

task or learner' familiarity with it" (Luchini, Quintana, & Soloway, 2004, p. 139).

The main purpose of examining three manufacturers is to identify what qualities each manufacturer provides in terms of product design. The product design can play an important role in its successful use, "We also found that creating dual-purpose interface elements, which provide both functionality and scaffolding, generally resulted in usable handheld tools" (Luchini et al., 2004, p. 139). In identifying which probeware products provide the dual-purpose interface, it can be determined which are more user-friendly. With the use of these user-friendly devices, students will be able to investigate and experience inquiry in the classroom. "Even if teachers have no initial computer experience they quickly discover investigative science questions they can ask and answer with handheld computers and probes" (Gado & Hooft, 2005, p. 340).

A good example of the hardships that go into a use of probeware in the classroom is with a project called the Smart Impact project that was performed in Benin, West Africa. "The SMART IMPACT project introduced handheld computers and probeware to Benin secondary science teachers to explore their attitudes toward technology

integration in inquiry-based science, conditions under which handheld technology and probeware can be used for inquiry, problem-solving, and critical thinking, and impact on student learning" (Gado & Hooft, 2005, p. 338). Sixteen physical science teachers were introduced to handheld computers and probeware. The teachers were given the appropriate training on the use of the instruments and their integration in the classroom. The teachers self-admittedly preferred their primitive tools of data collection but instantly saw the value of the new high-tech instruments for data collection. "Participants showed a positive attitude toward handheld computers and probeware as data collection and analysis tools" (Gado & Hooft, 2005, p. 339). The project also identified five conditions for the integration of these technologies in the classroom. "Data analysis generated five bottom line conditions for the infusion of handheld-based activities in the classroom: a) availability of equipment, b) small class size, c) small-scale action research, d) revision of the science curriculum, and e) statewide teacher training" (Gado & Hooft, 2005, p. 340). This project was implemented in West Africa, and although the school conditions are very different, the conditions generated are essential even in our educational system. The availability of the



equipment is only the beginning to the prerequisites of effective use in the classroom. The last condition is the most important condition. Without the training, every condition is useless. From this author's personal experience, it is the last step that lends the most difficulty to the process in our school system. In Benin, West Africa, the SMART IMPACT project came up with a list of concerns found with the integration of the technology in the classroom. "Four related categories of concern were found as well: a) funding and material costs, b) mastery of both traditional and innovative tools, c) lack of laboratories and electricity, and d) lack of technical assistance" (Gado & Hooft, 2005, p. 340). While the conditions are the prerequisites to the integration of the technology in the classroom, the concerns are the items that might prevent the meeting of the conditions. Although the concerns in Benin are a little more severe, we face many of the same limiting factors. Due to over crowding in the school system, funding and laboratories equipped to perform activities are limited.

#### Summary

With a complete understanding of inquiry and technology in the classroom, probeware can be a very

useful tool in the delivery of science content. The process for change is slow and begins with a single step. This project will begin the step towards the use of probeware in the classroom. In the next chapter, the criteria used in the comparisons among the probeware will be identified and explained.

## CHAPTER THREE

### METHODOLOGY

#### Introduction

Three exemplary experiments utilizing technology probeware were chosen with which to test each manufacturer's probes against a given set of criteria deemed to be essential when evaluating probes for purchase and use in the classroom. The exemplary experiments were chosen from each of the manufacturer's resources and were easily accessible from disks that accompany the probeware or through the manufacturer's resources. One exemplary experiment from each manufacturer was chosen to ensure equity in the evaluation process. Each manufacturer was ensured the opportunity to operate under ideal conditions designed for their particular hardware. The criteria used for establishing an experiment as exemplary included:

- Feasibility in a classroom environment;
- Ability to be inquiry based;
- Alignment to National Science Standards; and
- Ability to fit one or more graphical interpretations of the data being logged

The first exemplary experiment chosen for this study is from Pasco Scientific titled "Fruit Battery,"

(Griffith, 1999, p. 1-8) designed for use with a voltage probe. This simple experiment can be done in any classroom environment, and is chosen because of its simplicity. With this experiment, the probeware's data viewing and manipulation features will be tested.

The second exemplary experiment is from Vernier, titled "Mixing Warm and Cold Water," (Volz & Sapatka, 2000, p. 7-1) designed for the temperature probe. This experiment also uses supplies that are easily found or can be used in any classroom environment. This experiment allows the chance to compare the response rates and stability of the temperature probes.

The third exemplary experiment is from Onset titled "The Light Test- Colloid or Solution?" (The light test - colloid, 2002) designed for a light intensity probe. This experiment is slightly more difficult but still feasible in a classroom environment. The factor that limits the use of a classroom is the ability to remove external light sources. This would make it hard for teachers that have classrooms with windows or emergency lights, but not impossible. This experiment also allows an opportunity to compare the internal light sensor that the HOBO is equipped with and the external probes for the Pasco and Vernier.

Using the three exemplary experiments, one from each manufacturer's resources, the probeware will be reviewed according to a specific set of criteria. The three experiments are actually used as a control for reviewing the operation of the instruments. The review criteria is comprised of several aspects that teachers need to know and understand when considering the purchase of probeware for the classroom. Although several features were identified and tested, there are countless other features that will be tested under the operation of the units. It is during the operation of the instruments that the pros and cons could be identified. If there are any obvious operation problems or benefits, they will be identified and described. The first and in the author's experience, the most important criteria is how user-friendly is the probeware. No matter how beneficial a piece of equipment can be, if a teacher can not figure out how to use it, it will easily become wasted money and not used. The user-friendly aspect is divided into two separate, but equally important characteristics. The first is installation and setup, and the second is the actual operation of the equipment itself.

The criteria for comparison fall under two categories; general criteria and probe specific criteria.

The general criteria for comparison are the summation of all operation characteristics of the probeware itself. These criteria include the software system requirements, software installation, hardware system requirements, hardware installation, technical support, additional resources provided, software user interface, hardware user interface, pricing and availability, and the quality of construction. Each manufacturer will receive a score of one (low) to three (high) according to the criteria set forth in Table 1.

System requirement is a term heard all too often when purchasing computer software or hardware. Since probeware is integrated with computers, it is a term that needs to be considered. The minimum system requirements are the lowest specifications a computer can contain and still effectively and reliably run the required software as well as hardware. Schools have mixed levels of technology; the right decision on a probeware purchase might be the simple decision of which one will work with the computers available. If probeware is to be used, it is crucial that the computers used meet the minimum system requirements. If the minimum system requirements are not met, the software may not run properly or worst yet, the hardware might not have the appropriate connections to connect to

the computer. Failing to meet the software or hardware system requirements would render probeware useless, an ultimate waste of money.

The first step in the use of any computer integrated instrument is the installation process. The installation is a two step process, the installation of the hardware and then the installation of the software. The installation of the hardware should be the easier of the two, but there are still difficulties that might be encountered. The installation of the hardware includes the connection of the hardware to the computers, and the connection of the hardware to a power source. The installation of the software is a little more complex. The installation of the software includes the data manipulation software that should come with the probeware as well as the drivers needed for the computer to successfully recognize and link to the probeware. Without proper installation of the instrument, it would be impossible to use. The ease of the installation process are compared and reviewed. The identification of any accessories required and included or required but not included are also reviewed.

The hardware user interface only consists of what features can be accessed by use of the probeware hardware

only. Some probeware manufacturers have features that allow them to be used even when not connected to the computer. Then when the unit is connected to the computer, the data is transferred to the computer and can be manipulated accordingly. This is a desirable feature for teachers interested in field research. The probeware can be taken out of the classroom for any necessary investigations. The requirement of a portable power source is also necessity with the use of the probeware in the field.

The software user interface is one of the most important and critical components to probeware. It is the software that allows one to view the data being logged and manipulate the data in the ways needed. The options for recording data are identified and tested. The capability to manipulate data is crucial but just as crucial is the ease of doing so. Different options for displaying data are definitely a desirable feature when using probeware for various experiments. For some experiments a line graph might be desirable and efficient for displaying the appropriate data. Other times, a simple bar graph is sufficient for the occasion. Having these options is a must for effective classroom integration. To determine the quality of software user interface, the different options



for viewing the data are examined and manipulated. Features such as sampling rates and adjustable scales are also tested and reviewed.

The technical support provided by the manufacturer can be a lesson saving feature. Many teachers have a limited technical background, and even a little speed bump in the road can completely stop their use of probeware. Manufacturers can provide numerous tools of support which include but are not limited to frequently asked questions, trouble shooting manuals, and person to person technical support via phone or email.

The need for support does not stop with the support of technical problems. Once teachers have the equipment and know how to use it, the question still remains of when to use it in the classroom? Manufacturers provide a large range of resources for use with their products. The resources range from investigation ideas to entire prewritten labs for use in the classroom. The amount of resources as well as the quality of the resources will be put to the test in the comparison.

The next aspect might be equally important to administrators as it is to teachers. The next characteristic that is examined is the price of each manufacturer's probeware package. It is important to not

only know the prices of each set, but to also know what is the bare minimum required to get started in your classroom immediately. There are also programs that teachers can utilize to help them acquire the equipment for use in their classroom with little or no cost to them. In addition to the initial cost of the probeware, the cost and availability of additional probes is another important aspect. The range of accessories each manufacturer can use without the purchase of additional equipment is identified. With a large probeware purchase, teachers would be disappointed if they soon found that their probeware could not be expanded to fit any probe on the market. The compatibility with other probe manufacturers also fit within the pricing field. Can the probe of one manufacturer fit the hardware of the other? This aspect is important when considering an upgrade to another manufacturer. If the accessories from a previous purchase can be used with the next purchase, the school can save large quantities of money.

The quality of the construction of the hardware is an important aspect to consider when purchasing probeware. The quality of the construction is the size and sturdiness of the actual hardware. Dealing with students anywhere from the K-12 span, the durability of the hardware needs

to be a main concern. Students will, with no doubt, test the durability of any piece of equipment presented to them. If the equipment cannot hold up to the use of a student, it will not work in the classroom. Schools do not want to purchase replacement units every time the students get to use the probeware. Making judgments about the durability will be a difficult process without the completion of the destruction of the unit. The judgments will have to be based on the observations made about the hardware units.

The probeware will also be compared under the probe specific experiments. Each of the three probes are also reviewed during their operation in the exemplary experiments. The criteria and characteristics are described in Table 2.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### Introduction

The three probeware instruments were used and evaluated through the experimentation, research, and use of each. The results for the comparison of the general characteristic are shown in Table 3. In addition to the scores assigned to the individual criteria, all the scores were added for each of the manufacturers, which gave each manufacturer a total score. The higher this total score was, indicated the inclusion of more desirable features. Both Pasco and Onset received a total score of 20, and Vernier was not too far ahead with a total score of 21.

#### Presentation and Discussion of the Findings

The system requirements of each of the manufacturer's products were fairly low; there were no unusually high requirements by any of the probeware products under review. Pasco's ScienceWorkshop had the lowest system requirements, being able to function with a Pentium 1 or equivalent working with Windows 98 or higher with only 16 MB of RAM (Data Studio : features and, 2006). ScienceWorkshop came equipped to work with a standard serial port, which is the older type of hardware

connection. The standard serial connection was an outdated connection type recently removed from some of the newer computer and laptop products. Without a serial connection on a computer, the purchase of a converter is required. Vernier's LabPro had slightly higher software system requirements, but not unreasonable. It could have run on a Pentium 1 with Windows 98 or higher, but the running speed must be at least 200 MHz, with 32 MB of RAM (Logger pro 3: quick reference, 2006, p. 2). The LabPro could be connected using the USB port or the serial port, both came standard with the initial LabPro purchase. The HOBO from Onset had the highest system requirements. The HOBO requires a computer running Windows 2000 or higher and 256 MB of RAM (HOBOWare Software, 2006). The HOBO could only be connected using a USB port, which may not be included on an older computer.

The hardware installation process was only a difficult process with regards to the ScienceWorkshop. The process was as simple as one USB plug and the auto detection of the installed interface with both the HOBO and LabPro, which earned both manufacturers a score of three for hardware installation. The difficulty arose with the ScienceWorkshop's serial port. The computer used for the project did not have a serial port; in turn a USB to

Serial converter was purchased and used. There were several additional steps required to make the ScienceWorkshop functional. As for the power source, all three were capable of using a battery power source. Both Vernier and Pasco also had external power adaptors.

All three manufacturers provided numerous forms of technical support. Online support, phone support, email support, and fax support were all standard forms of technical support provided by each of the manufacturers. The standard technical support is where Onset ended with their attempts at technical support. Both Vernier and Pasco took technical support a little farther. Vernier also offered training on how to use their products in a classroom. Pasco also offered training as well as workshops and professional development. The support with additional resources for the teacher was also tested. Onset had multiple programs designed to help teachers integrate probeware in the classroom. Onset had teacher loaner programs that allowed teachers to borrow a classroom set of probeware for a two month period at no cost to the teacher. Onset also provided 300 labs to use with their products at no cost. Pasco came in second by also providing labs at no additional cost. Vernier's additional resources were few and far in between. There

were only a couple example labs available for free, most of the resources provided on their website were offered for an additional cost.

When comparing the similar equipment purchase prices, Onset was the least expensive, Vernier and Pasco was fairly close in price, with Vernier just a little less expensive. The HOBO from Onset was the least expensive piece of equipment. The interface was nearly \$100 cheaper than the next in line. The other money saving feature was the internal sensors that the HOBO came equipped with. Neither the Pasco nor the Vernier had internal sensors. The HOBO also had the teacher loaner program. The Pasco was just slightly more expensive than the Vernier when it came to the interface and sensors. The Vernier also came equipped with the USB and Serial connectors as well as with one voltage sensor which placed it comfortable in second place for price efficiency. All three manufacturers had probes that were backward compatible with other interfaces in their product lines. This would make it possible to purchase upgraded interfaces without having to purchase the probes again.

LabPro from Vernier was the only interface with auto detect sensors. Once the sensor was connected to the interface, it was ready to take measurements. The HOBO was

not as easy but still was not difficult. When launching the probeware for data collection, one had to select the appropriate probe from the available list. The ScienceWorkshop from Pasco was the hardest to load the probes on the interface. Once the probe was attached to the interface, the appropriate probe was selected from a list. The list of probes was quite lengthy and contained several similar items which made the selection a little confusing.

The quality of the construction of each manufacturer's probeware was a difficult criterion to judge. The HOBO was the smallest and also the lightest interface. The small size was an advantage due to its ability for easy storage but its weight was indicative of cheap composition, which might have led to easy breakage. The ScienceWorkshop was much sturdier than the HOBO, but neither could compare to the construction of the LabPro. The ScienceWorkshop was fairly sturdy, but large and awkwardly shaped for field use. The LabPro was fairly large but designed to fit in the palm of a hand. With the design and quality aspect in mind, the LabPro was a desirable interface to purchase.

The software user interface showed the most difference between the three manufacturers. Pasco's



ScienceWorkshop used software by the name of Data Studio, which had the most features but with these features came complexity. The data gathered by the ScienceWorkshop could be viewed with several different formats. These formats include digits, graph, histogram, meter, scope, table, and FFT graph. The other manufacturers did not have such a wide range of formats for viewing the data. Vernier, using software named LoggerPro 3, had four formats which include FFT Graph, Strip Chart, histogram, and graph. The HOBO from Onset, using software by the name of HOBOWare, had the fewest features with only a data table and graph. The need for the different graph types became quite evident when reviewing the results for the fruit battery lab activity. In this experiment we saw a perfect example of data, results shown in Table 4, which was not be best viewed with the standard graph. Figures 1, 2, 3, show the graphical representation of one run from each of the manufacturers. The graphs were very simple and the data was consistent. The ScienceWorkshop was able to view the data in far more effective ways, shown in Figures 4 and 5. This experiment was an example of an activity that really only required a quick reading of the voltage. Then the students would make other quick readings of different

fruit batteries to make a data table comparing the fruit used.

Pasco's Data Studio was the only product with the ability to graph multiple runs on the same graph. Figure 6 shows two runs for the mixing hot and cold water experiment. Each run was illustrated with different colors and data point shapes which made identification of each run easy. Run One was shown in red with each data point as a triangle. Run two was shown in blue with each data point as a circle. Pasco was the only product with these capabilities.

Onset's HOBOWare was unable to view the data real time. The probeware was set by the computer to start data logging at a predetermined time, and then the data was logged and stored on the hardware itself. The data was not sent to the computer until after the logging was complete. After the completion of the data run, the data could be viewed and graphed.

There were very few differences discovered between the manufacturers when examining the different probes used in the three exemplary experiments. The comparison between each manufacturer is shown in Table 5. The main difference was in the quality of the different probes. The voltage probe was a very simple connection to the probeware

interface, but the difference between the manufacturers was large. The Onset voltage connection was just the bare wires, shown in the Figure 7, which made it difficult to use. It was a necessity to purchase additional connector wires with alligator clips. Vernier had hook clips, also shown in Figure 7, which were far more convenient to use and alligator clips were only necessary when the connection needed to be larger than the hook. Pasco had the best quality connection, equipped with large opening alligator clips. At no time during the experiment was another connection needed with the Pasco voltage probe. In addition to the connection types, the Pasco voltage sensor had the thickest wire which was a desirable feature.

The light sensors also showed large differences in quality. The Pasco light sensor probe was of the highest quality. The Vernier was a close second, but the internal light sensor that came equipped with the HOBO was a little cheaper. With the HOBO, it was difficult to get a consistent reading, even when the light source was consistent. An image of all three light sensors is shown in Figure 8. Under the same light conditions, the graphical display of the data appeared much different with the HOBO light sensor, shown in Figure 9. The HOBO had a difficult time working with minimal background light

conditions. The peak for the background light was saturated which means the spectral range was too low. The two measurements received very little response as well.

The "Mixing Warm and Cold Water" experiment resembled a traditional lab. With this experiment, the reliability of the probes as well as the functionality was tested. The data and results for the mixing warm and cold water experiment are shown in Table 6.

There was no significant difference in the data produced by the three manufacturers. The Pasco was the more precise unit, with the smallest difference between the two runs. The temperature probes themselves were very similar, each of similar length and of stainless steel construction; Pasco had a stainless steel core coated with a Teflon protective layer. Images of each probe are shown in Figure 10. The graphs made from the data also show the quality of the probe itself. Both graphs created from the Pasco data were far less smooth than the other two manufacturers, shown in Figure 11. This indicated a slow response time when dealing with changes in the temperature. It took a long time to level out the temperature reading. The slow response time could be attributed to the Teflon coating of the Pasco temperature sensor. The Teflon coating could prove beneficial when

taking the temperature of corrosive materials, but in this case it slowed down the response time. The other two manufacturers had very smooth transitions between the temperature changes.

Table 1. General Characteristic Scoring Rubric

Score	Characteristics
3	The probeware manufacturer that scores a three will have more characteristics that are identified as advantageous for use in the classroom.
2	The probeware manufacturer that scores a two will have the second most characteristic that are identified advantageous for use in the classroom.
1	The probeware manufacturer that scores a one will have the least characteristics that are identified as advantageous for use in the classroom.

Table 2. Probe Specific Criteria

Voltage Probe	
Voltage Range	Description: The range of voltage the probe can accurately and safely measure
Connection Type	Description: The connection type fixed to the end of the voltage probe.
Quality	Description: The quality of the construction
Light Intensity Probe	
Sensitivity	Description: How sensitive is the light to background light sources.
Quality	Description: How well made is the light probe itself.
Temperature Probe	
Size	Description: The length and diameter of the probe.
Temperature Range	Description: The range of temperatures that the probe can accurately read.
Probe Composition	Description: What material is the probe composed of.
Response Time	Description: How long does the probe take to adjust to a change in temperature?

Table 3. General Characteristics Results

Criteria	Pasco	Vernier	Onset
Software System Requirements	3	2	1
Software Installation	3	1	2
Hardware System Requirements	1	3	2
Hardware Installation	1	3	3
Technical Support	3	2	1
Additional Resources	2	1	3
Software User Interface	3	2	1
Hardware User Interface	1	2	3
Pricing and Availability	1	2	3
Quality of Construction	2	3	1
Score Total	20	21	20

Table 4. Fruit Battery Results

Manufacturer	Voltage (in volts)
Pasco	0.85
Vernier	0.93
Onset	0.60

Table 5. Probe Comparison Results

Voltage Probe			
	Pasco	Vernier	Onset
Voltage Range	-10 to +10 volts	-10 to +10 volts	0-2.5 volts DC
Connection Type	Alligator Clips	Hook Clips	Bare Wires
Quality	Pasco voltage sensor had the thickest wires.	Vernier voltage sensor had thick wires up until the hook clips	Onset voltage sensor had no connectors, only three exposed wires
Pasco: <a href="http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1410&amp;Detail=1">http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1410&amp;Detail=1</a> Vernier: <a href="http://www.vernier.com/probes/vp-bta.html">http://www.vernier.com/probes/vp-bta.html</a> Onset: <a href="http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#voltage">http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#voltage</a>			
Light Intensity Probe			
	Pasco	Vernier	Onset
Sensitivity	5-500 lux	0-600 lux	10-32280 lux
Quality	small and durable	Contains glass tube which can be easily broken	Internal sensor comes with HOBO, difficult to take readings
Pasco: <a href="http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1352&amp;Detail=1">http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1352&amp;Detail=1</a> Vernier: <a href="http://www.vernier.com/probes/ls-bta.html">http://www.vernier.com/probes/ls-bta.html</a> Onset: <a href="http://www.onsetcomp.com/Products/Product_Pages/hobo_u12_loggers/U12_family_data_loggers.html">http://www.onsetcomp.com/Products/Product_Pages/hobo_u12_loggers/U12_family_data_loggers.html</a>			
Temperature Probe			
	Pasco	Vernier	Onset
Size	Length = 190 mm Diameter = 7 mm	Length = 105mm Diameter = 4mm	Length = 102 mm Diameter = 3 mm
Temperature Range	-05 to 105°C	-40 to 135 °C	-40 to 100 °C
Probe Composition	Teflon Coated Stainless Steel	Stainless Steel	Stainless Steel
Response Time	NA	10 seconds in water	15 seconds in water
Pasco: <a href="http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=51390&amp;Detail=1">http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=51390&amp;Detail=1</a> Vernier: <a href="http://www.vernier.com/probes/tmp-bta.html">http://www.vernier.com/probes/tmp-bta.html</a> Onset: <a href="http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#steel">http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#steel</a>			



Table 6. Mixing Hot and Cold Water Results

Run	Warm Water Temperature In °C	Cold Water Temperature In °C	Heat Gained by Cold Water in Joules	Heat lost by warm water in Joules	Percent Difference
Pasco Run 1	40	9	3135	3344	6.25
Pasco Run 2	33	8	2508	2717	7.69
Onset Run 1	45	4	4389	4180	-5.0
Onset Run 2	44	3	4389	4807	8.69
Vernier Run 1	38	3	3553	3762	5.55
Vernier Run 1	45	4	4598	3971	-15.79

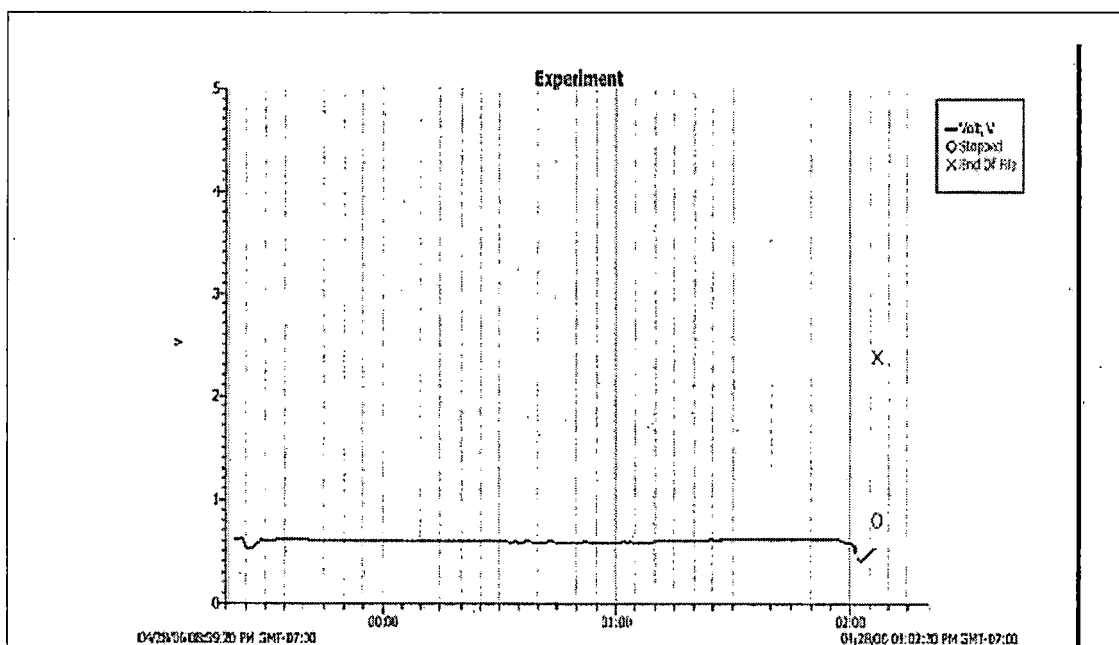


Figure 1. Onset Voltage versus Time Graph

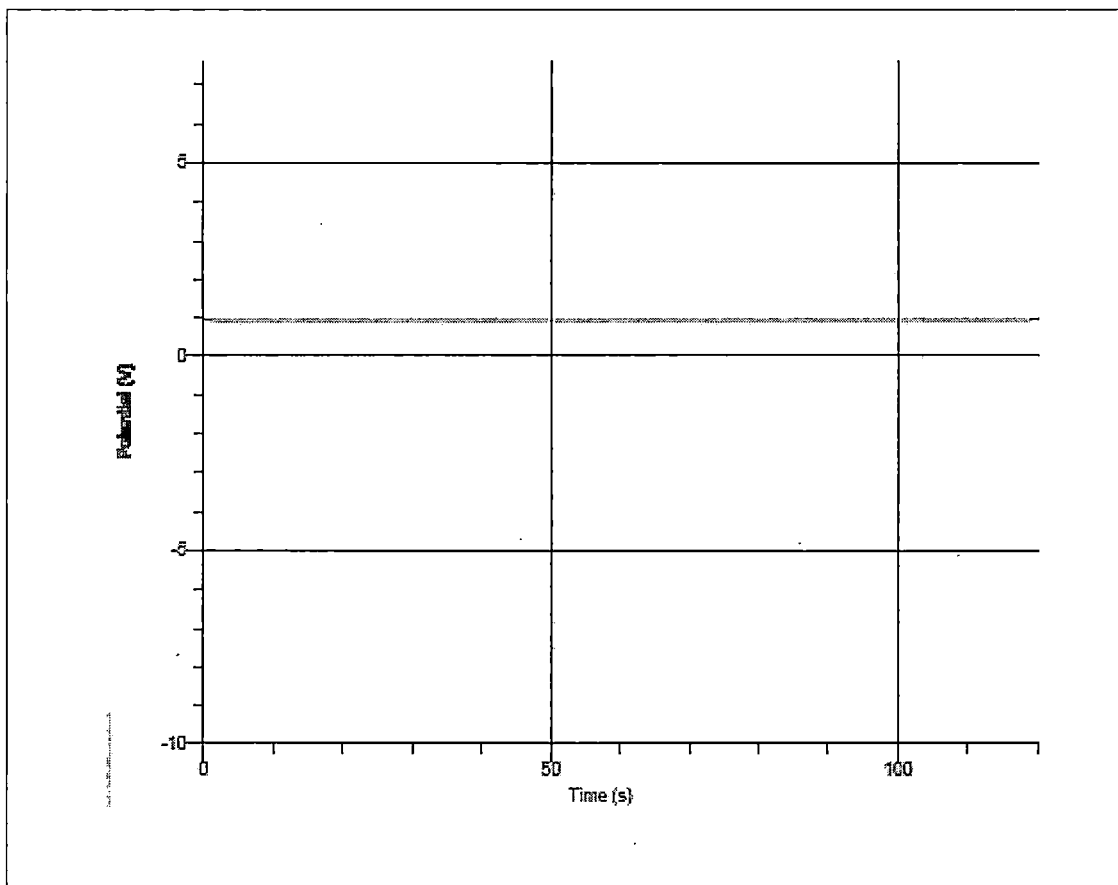


Figure 2. Vernier Voltage versus Time

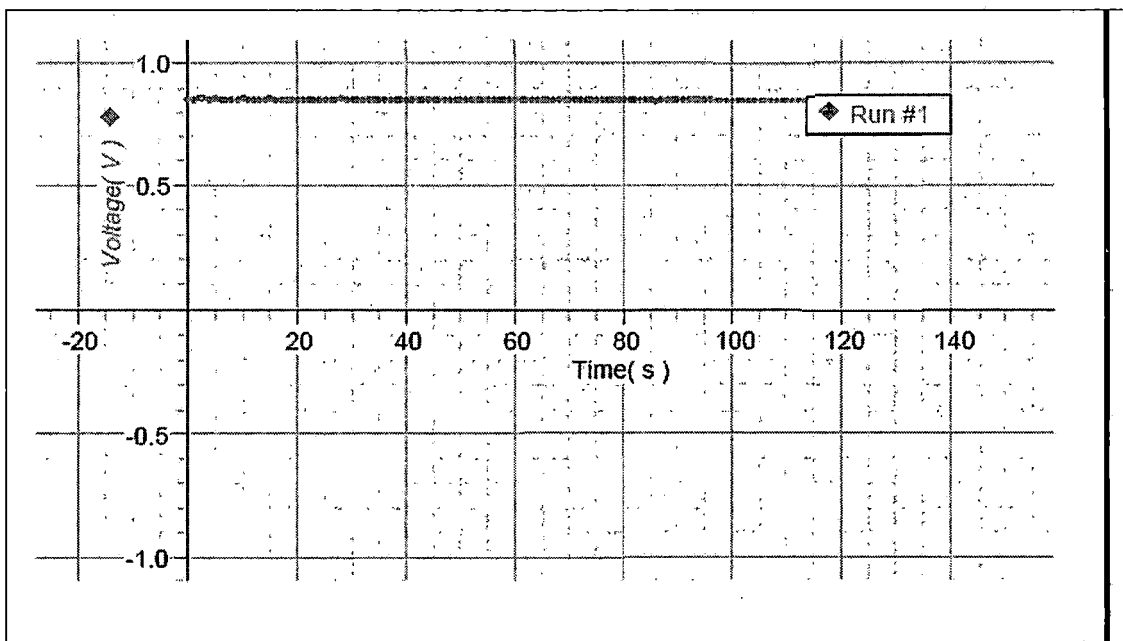


Figure 3. Pasco Voltage versus Time Graph

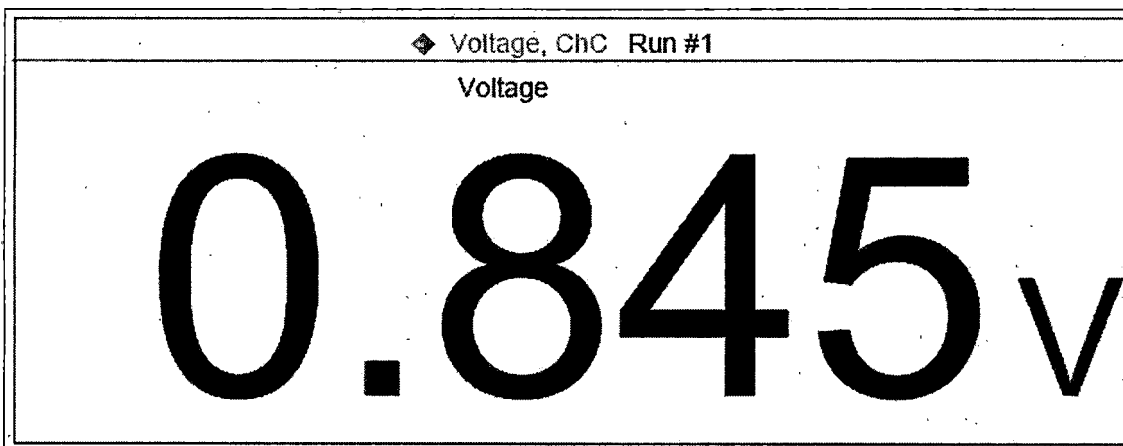


Figure 4. Voltage Digital Reading

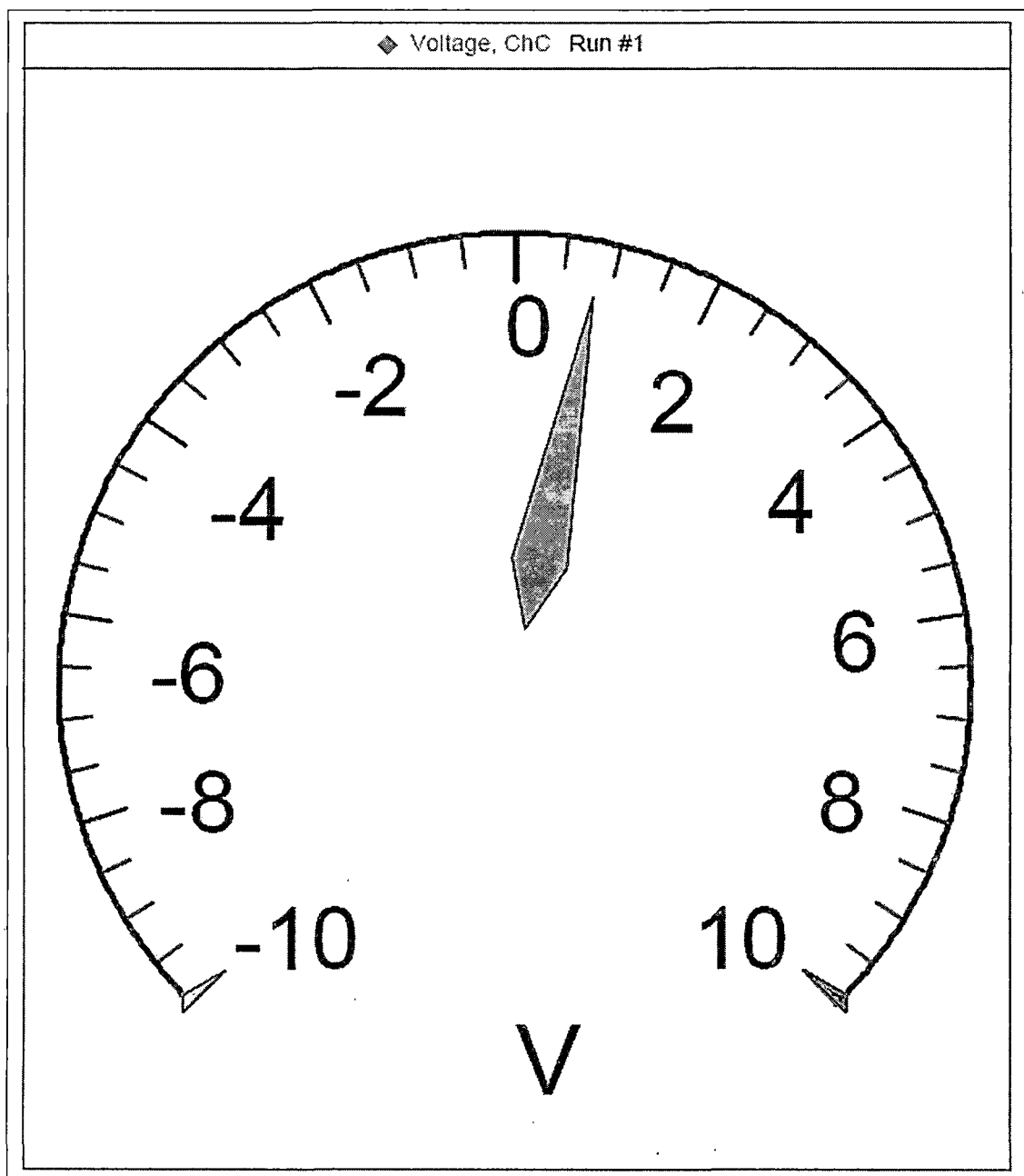


Figure 5. Voltage Meter

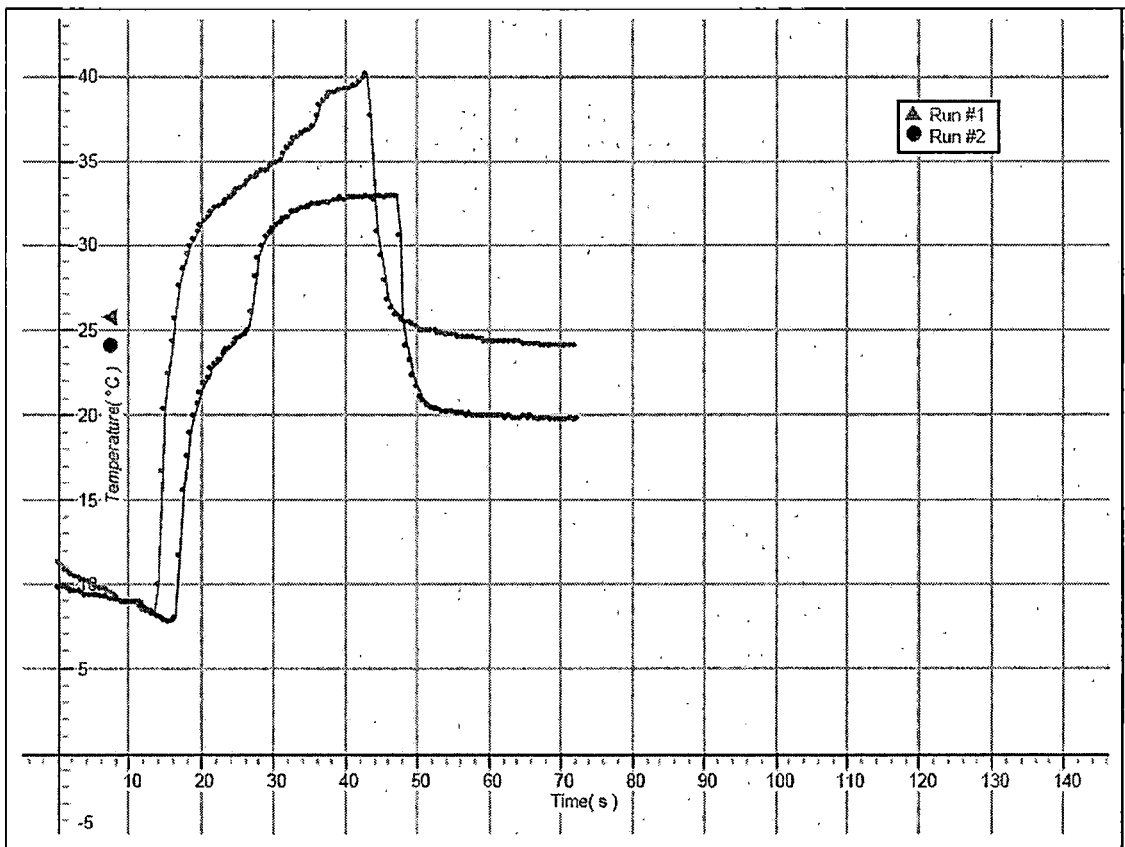


Figure 6. Temperature versus Time Graph

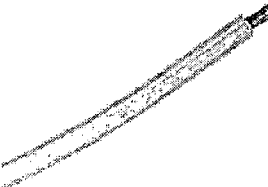
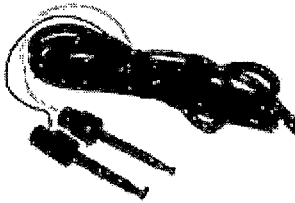
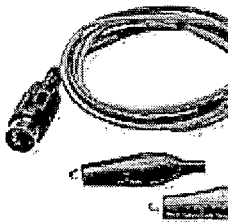
A. Onset Voltage Input Cable (CABLE-2.5-STEREO)	B. Vernier Voltage Probe (VP-BTA)	C. Pasco voltage Sensor (CI-6503)
		
<p>Image Sources:</p> <p>Pasco: <a href="http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1410&amp;Detail=1">http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1410&amp;Detail=1</a></p> <p>Vernier: <a href="http://www.vernier.com/probes/vp-bta.html">http://www.vernier.com/probes/vp-bta.html</a></p> <p>Onset: <a href="http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#voltage">http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#voltage</a></p>		

Figure 7. Voltage Probes

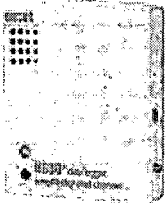
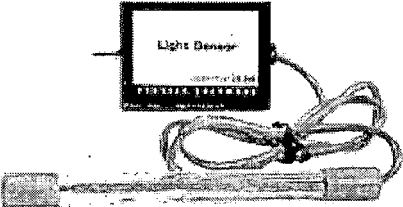
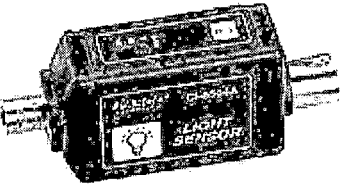
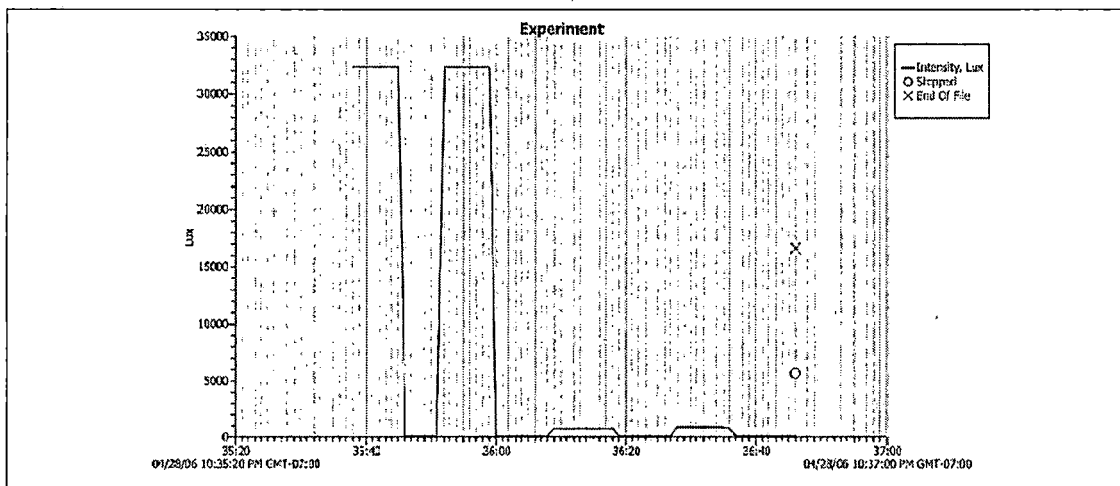
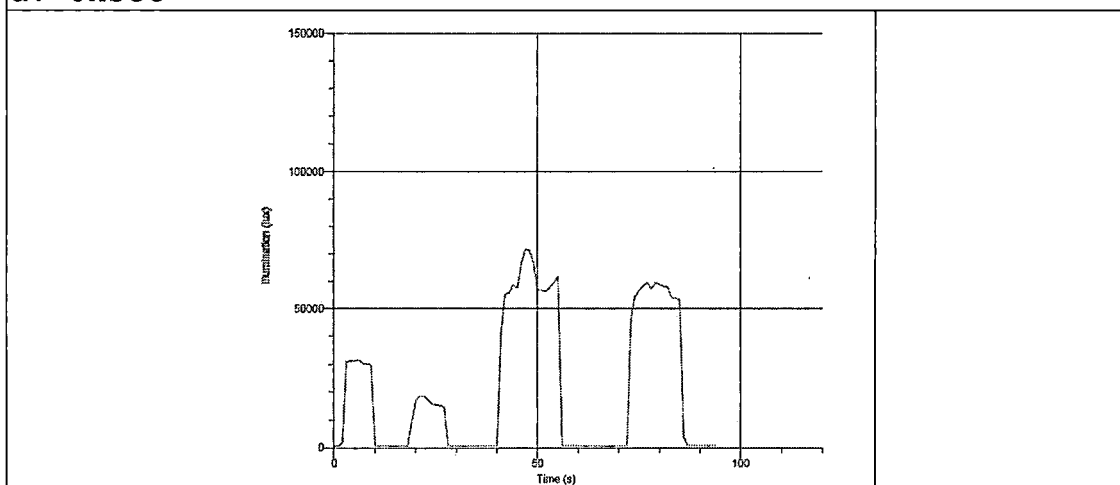
a. Onset	b. Vernier	c. Pasco
		
<p>Image Sources:</p> <p>Pasco: <a href="http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1352&amp;Detail=1">http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=1352&amp;Detail=1</a></p> <p>Vernier: <a href="http://www.vernier.com/probes/ls-bta.html">http://www.vernier.com/probes/ls-bta.html</a></p> <p>Onset: <a href="http://www.onsetcomp.com/Products/Product_Pages/hobo_u12_loggers/U12_family_data_loggers.html">http://www.onsetcomp.com/Products/Product_Pages/hobo_u12_loggers/U12_family_data_loggers.html</a></p>		

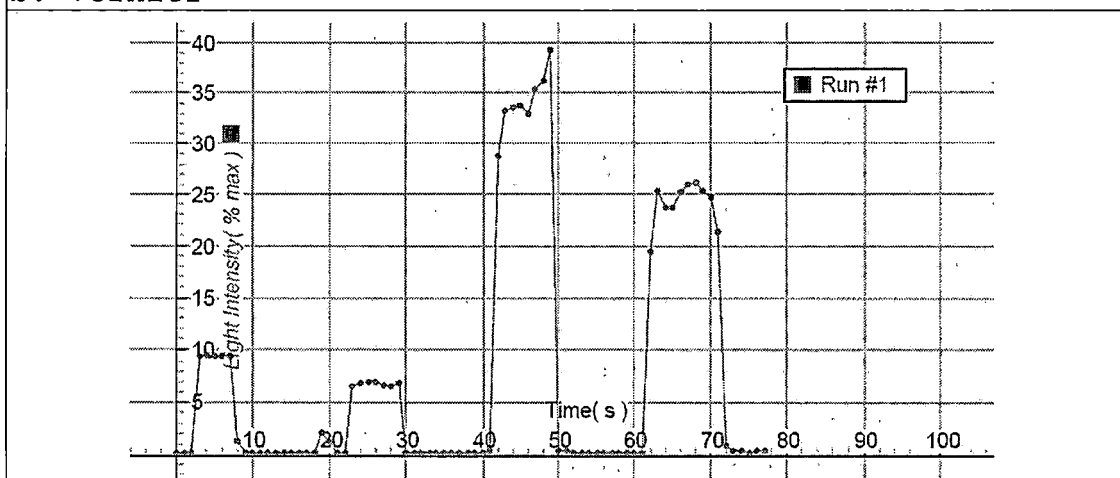
Figure 8. Light Intensity Probes



a. Onset



b. Vernier



c. Pasco

Figure 9. Light Intensity Graphs


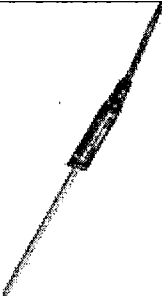
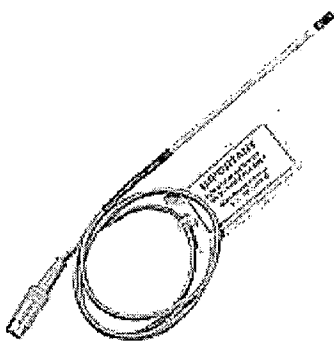
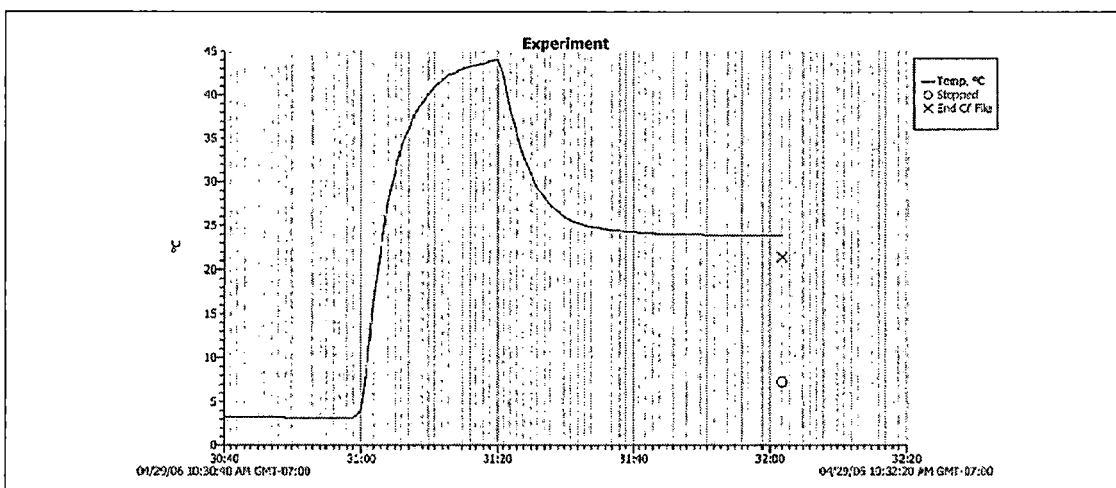
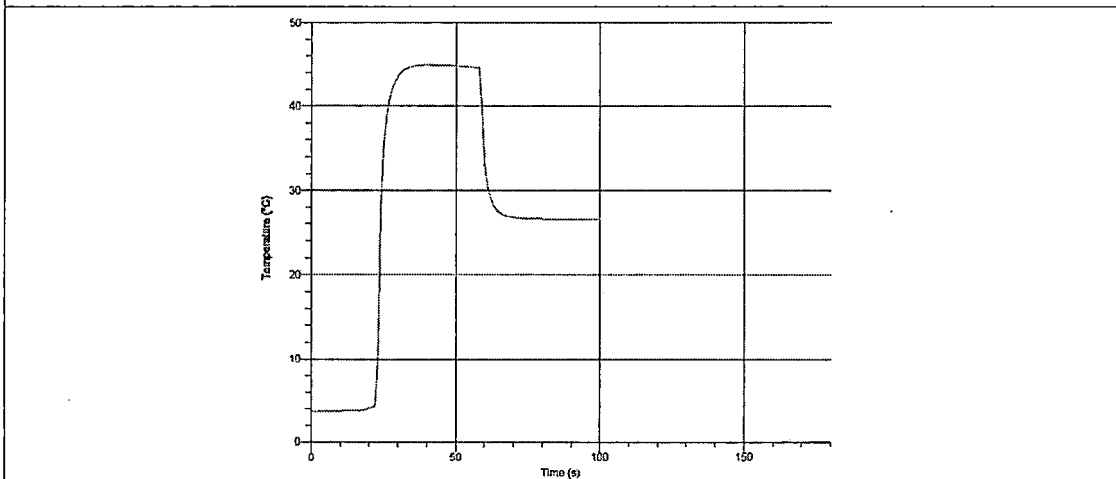
a. Onset	b. Vernier	c. Pasco
		
<p><i>Image Sources:</i>  Pasco: <a href="http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=51390&amp;Detail=1">http://store.pasco.com/pascostore/showdet1.cfm?&amp;DID=9&amp;Product_ID=51390&amp;Detail=1</a>  Vernier: <a href="http://www.vernier.com/probes/tmp-bta.html">http://www.vernier.com/probes/tmp-bta.html</a>  Onset: <a href="http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#steel">http://www.onsetcomp.com/Products/Product_Pages/HOBO_H08/external_sensors.html#steel</a></p>		

Figure 10. Temperature Probes

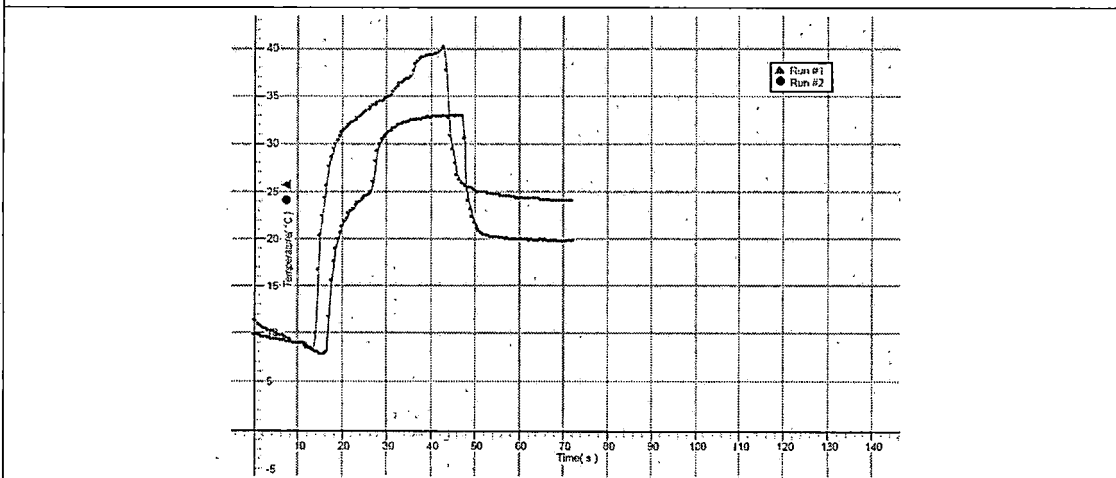




a. Onset



b. Vernier



c. Pasco

Figure 11. Mixing Warm and Cold Water Graphs

## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### Introduction

Based on the data in this study no manufacturer proved themselves to be clearly the best. The decision on whether to buy a particular manufacturers probeware turned out to be far more complex. There was no significant difference between the Vernier, Pasco, and Onset when comparing the entire product based on their total criteria comparison scores of 21, 20, and 20 respectively. A look at the particular features that are important to a prospective teacher or school interested in a purchase will ultimately decide which product is best for them.

#### Conclusions

The HOBO from Onset definitely had features that were desirable for certain groups. The HOBO was the least complex unit of the three reviewed in the project. With a low complexity, this would be an ideal probeware unit for elementary schools. The minimal options create the perfect learning environment for the younger students. Students would not get lost in the overly complicated technology but would have time to master the content being demonstrated by the experience.

HOBO was also the perfect product for schools that do not have the budget for a large probeware purchase. HOBO was the least expensive of the three manufacturers but that was half the benefit. HOBO also had teacher programs that allow teachers to borrow a classroom set of HOBO probeware and probes for a two month period with no cost to the teacher.

The fact that the HOBO was unable to view the real time data as it was being logged makes it ineffective for the high school classroom and for lecture demonstration purposes. HOBO appeared to be designed for field logging. Once the logging was complete, the data could be viewed and displayed on a graph. This made it difficult to do labs that were cause and effect based. The time had to be closely watched and actions were matched to the desired time. If something had gone wrong, it was discovered at the end on the run, and the run had to be repeated.

The Labpro from Vernier also had its own audience. The LabPro was incredible easy to use, with its auto detect sensors, it was almost fool proof. The LabPro was the perfect product for up to the junior high school level. The limited options for graphically viewing data and data manipulation made the perfect level of complexity for the junior high school age group. The ease of the

operation of the LabPro definitely made it an appealing interface.

The ScienceWorkshop from Pasco had the most features that would be essential to for higher level inquiry activities. The multiple graphing methods and ability to graph multiple runs on the same graph allowed for easy analysis of the data. This was the most complex unit in the review process. The ScienceWorkshop had more options for the viewing and manipulating data. In a high school classroom, these options are essential for lessons.

#### Recommendations and Limitations

With the introduction of new probeware products each day, the introduction of a product that encompasses all the best most desirable features could be just around the corner. The purpose of this project is to familiarize teachers with probeware that once a teacher knows what features are beneficial to their needs, they can become informed consumers, regardless of changes in the market. To completely cover the span of probeware, this author recommends the comparison of a larger sample of probeware manufacturers. In addition to a larger sample size, the probeware product lines should represent the latest technology provided by each of the manufacturers selected

for the comparison, which would overcome the limitations presented in this project.

### Summary

Based on the data in this study no manufacturer proved themselves to be clearly the best. With respect to each criteria examined, it was easy to see that one of the manufacturers had features that were more beneficial than the others, for example Onset was clearly the most efficient interface. When looking at all the criteria collectively, the benefits and drawbacks appeared to level each other out, evident by their total scores. The option of which interface to purchase easily becomes a choice of which characteristics are more important and useful in a teacher's classroom. With an expanded knowledge of probeware, a teacher should have no problem making the decision of which characteristics are important and ultimately decide which interface is the most beneficial to them.

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